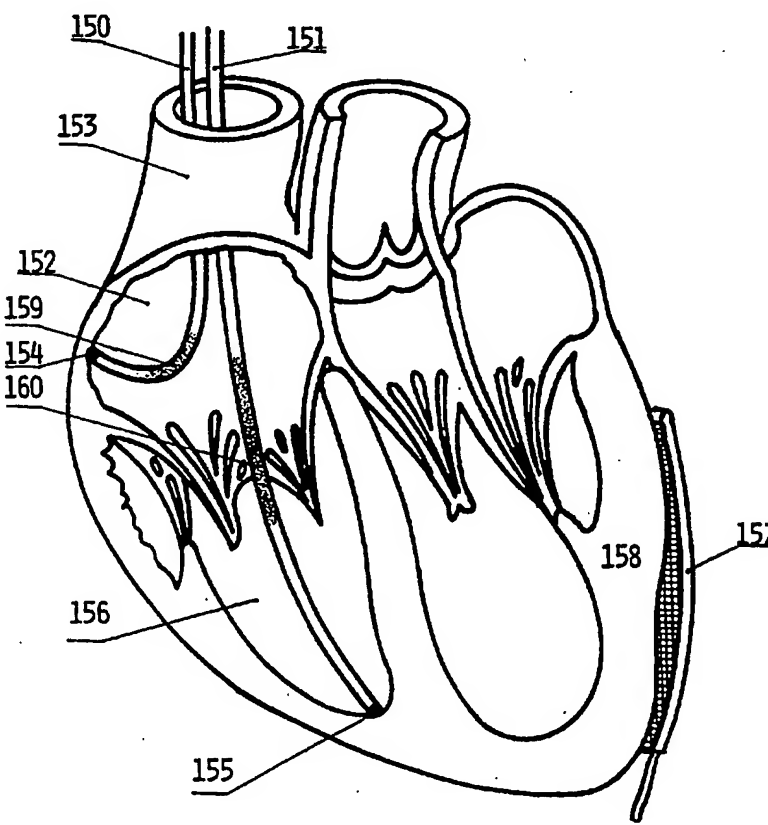




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁶ : A61N 1/365</p>	<p>A1</p>	<p>(11) International Publication Number: WO 95/19201</p> <p>(43) International Publication Date: 20 July 1995 (20.07.95)</p>
<p>(21) International Application Number: PCT/EP95/00113</p> <p>(22) International Filing Date: 12 January 1995 (12.01.95)</p> <p>(30) Priority Data: P940023A 12 January 1994 (12.01.94) HR</p> <p>(71) Applicant (for all designated States except US): PACSETTER AB [SE/SE]; S-171 95 Solna (SE).</p> <p>(72) Inventor; and (75) Inventor/Applicant (for US only): FEREC-PETRIC, Bozidar [HR/HR]; Sovinec 17, 41000 Zagreb (HR).</p> <p>(74) Agent: BLUMBACH, KRAMER & PARTNER; Radeckestrasse 43, D-81245 München (DE).</p>		<p>(81) Designated States: JP, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</p> <p>Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>
<p>(54) Title: CARDIAC ELECTROTHERAPY SYSTEM WITH CARDIAC CONTRACTION SEQUENCE MEASUREMENT</p> <p>(57) Abstract</p> <p>A cardiac electrotherapy device comprises at least two cardiac electrotherapy leads (151, 157), said leads comprising sensor portions (160, 157) adapted to detect cardiac contractions in two different regions (156, 158) of the heart through a deflection of said leads (151, 157), electronic circuitry (173-181, 185) connected to or connectable to said leads and adapted to generate cardiac contraction data signals (B, C, D) corresponding to a detection by said sensor portions, and cardiac arrhythmia detection means operating in response to said cardiac contraction data signals and capable of detecting cardiac arrhythmia therefrom.</p> 		

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CARDIAC ELECTROTHERAPY SYSTEM WITH CARDIAC CONTRACTION
SEQUENCE MEASUREMENT

Field of the Invention

- 5 This invention relates to cardiac pacemakers and implantable cardioverters - defibrillators, in general, and to a cardiac electrotherapy device in particular.

Background and Prior Art

- 10 A device which has been disclosed in the U.S. Pat.No. 4,790,317 can automatically recognize the pathologic rhythm by means of monitoring of the pulse sequence representing the ventricular electrical activity. The disclosed device measures the timing sequence of electrical depolarization of the heart. Different ventricular rhythms can be identified by a specific different ventricular depolarization wave spread. Detection of either epicardial
15 or endocardial potential on at least two different points of ventricular muscle provides a specific timing sequence of ventricular depolarization for every kind of ventricular rhythm. Therefore at least two sensing positions on the ventricles are used, but more sensing points will obtain better discrimination between normal and pathologic rhythms as well as between various pathologic rhythms. If the multiple points ventricular sensing is combined
20 with atrial potential sensing, the specific timing sequence may be obtained in order to detect and discriminate various supraventricular arrhythmias.

- U.S. patent No. 5,261,418, U.S. patent No. 5,271,392 and EP 0 473 070 A2 discloses a device for lead tension measurement comprising so-called tensiometric transducers. These
25 transducers may be produced of either the piezoelectric material or the conductive rubber. Both materials may be used for production of tensiometric stylets. In these patent applications, there is a possibility to use a standard pacing lead for tensiometric measurement. Normally, the stylet channel of a lead enables the control of the lead implantation by means of a steel wire (stylet) insertion. Manipulating the stylet i.e. rotating, pushing and
30 pulling governs the direction of the lead tip. After the proper positioning of the lead tip,

the stylet is pulled-out. Therefore every implanted lead comprises an empty stylet channel which may be used for the permanent insertion of a stylet which may be used for lead tension measurement. European Pat.No. 461 539 as well as U.S. Pat.No. 4,291,707 specify a tensiometric patch. U.S.Pat.No. 5,109,842 discloses a motion sensor which may
5 be mounted onto the restricted and relatively small area of a defibrillator patch. None of these systems disclose the use of at least two sensors.

It is an object of the present invention to provide an improved device for detecting pathologic tachycardias, and for enabling a more accurate differentiation between various types
10 of tachycardias.

The object is achieved by the cardiac electrotherapy device according to claims 1 or 8. Preferred embodiments are described in the dependent claims.

15 Summary of the Invention

According to the present invention the device is incorporated within an implantable electrotherapy apparatus in order to achieve the measuring of the mechanical contractions of the heart muscle. Therefore, the mechanical activity of the heart is used for the
20 purpose of the present invention, instead of the electrical activity as described in the prior art.

At least two of the elastic tensiometric strips are mechanically coupled to the heart muscle on the two different positions. Either analysis of the electric signals or measurement of
25 the resistivity variations produced within the multiple tensiometric strips and caused by means of the cardiac muscle contractions, provides monitoring of the mechanical activity of the heart in such a way as to obtain the timing sequence of mechanical contraction of the heart.

30 The disclosed device yields a detection of the mechanical contraction sequence of the heart

which is characteristic for a certain type of cardiac rhythm, thus enabling exact detection of the pathologic cardiac rhythm as well as differentiation of various cardiac arrhythmias. The device can monitor the ration of amplitudes of at least two tensiometric transducer signals for the purpose of detection of the pathologic cardiac rhythm as well as differentia-
5 tion of various cardiac arrhythmias.

These and other aspects of the present invention will be more readily understood by reference to the following description and accompanying drawings in which

10 Fig. 1 is a cross-sectional four-chamber view of a human heart having implanted the atrial and the ventricular pacing lead as well as the left ventricular patch.

Fig. 2 discloses the input circuits for the cardiac contraction sequence measurement.

15 Fig. 3 shows the electrocardiogram and the corresponding output waveforms of circuits from previous Fig..

Description of the Preferred Embodiment

20 In the embodiment of Fig. 1 there is disclosed a four-chamber cross-section of the human heart having implanted the atrial 150 as well as the ventricular 151 cardiac pacing lead. Both leads enter the right atrium 152 through the superior vena cava 153. The atrial lead is a J-shaped lead comprising an electrode 154 on its tip which is positioned in the right atrial appendage. The ventricular lead has an electrode 155 on its tip which is positioned
25 in the right ventricle 156 in the apical position. Epicardial cardioversion patch 157 is implanted on the left ventricular free wall 158. Though unipolar leads are disclosed, bipolar leads would be also implanted in the same anatomic relation to the heart chambers. Every contraction of the heart muscle deflects both pacing leads as well as the patch. The atrial contraction causes the bending of the atrial lead while the ventricular contraction
30 causes the bending of the ventricular lead as well as of the patch. Magnitude of the lead

deflection depends on the radial lead stiffness and on the heart muscle contraction forces. Magnitude of the patch deflection depends on the patch stiffness and on the heart muscle contraction forces.

5 The bending segment 159 of the lead 150 implanted in the right atrial appendage is shaded gray, as well as it is the bending segment 160 of the ventricular lead 151. Because the patch 157 is fixed with its entire body to the left ventricular wall 158, the entire patch is bended by the left ventricular wall contraction. Actually, the ventricular lead bending forces are mainly caused by the right ventricular contraction. Therefore the timing
10 sequence between the ventricular lead 151 bending and epicardial patch 157 bending corresponds to the timing sequence between the right ventricular and left ventricular contraction. In normal sinus rhythm or in rhythm of ventricular pacing, there will be always some delay of patch 157 bended relatively to the ventricular lead 151 bending. In ventricular tachycardia, this delay may be changed or even inverted in the manner that
15 patch 157 is bending first and then lead 151 after certain delay. If leads and patch are tensiometric, such as disclosed in U.S. Patent No. 5,261,418, the signals of tensiometric transducers will provide the timing sequence of cardiac mechanical contraction.

In the embodiment of Fig. 2, there is disclosed a block diagram of the input circuit for
20 cardiac contraction sequence measurement by means of tensiometric leads and tensiometric patch implanted as disclosed in previous Fig. 1. The tensiometric transducers of the atrial lead 170, ventricular lead 171 and ventricular patch 172 are connected to the corresponding amplifiers 173, 174 and 175, respectively. The outputs of the amplifiers 173, 174 and 175 are connected to the voltage comparators 176, 177 and 178, respectively. The outputs
25 of the comparators 176, 177 and 178 are connected to the inputs of retriggerable monostable multivibrators 179, 180 and 181, respectively. The output 182 of multivibrator 179 provides a pulse representing the moment of atrial lead tension, i.e. right atrial appendage contraction. The output 183 of multivibrator 180 provides a pulse representing the moment of ventricular lead tension, i.e. right ventricular contraction. The output 184 of
30 multivibrator 181 provides a pulse representing the moment of ventricular patch tension,

i.e. left ventricular contraction. Reference voltage for comparators is generated by means of a precise programmable voltage level source 185.

In the embodiment of Fig. 3, there are disclosed the waveforms of electrocardiogram and corresponding output pulses from multivibrators 179, 180 and 181. Waveform A shows the electrocardiogram having P-wave 190, QRS complex 191 and T-wave 192. Waveform B are the pulses provided at the output 182, designating the occurrence 193 of the atrial appendage contraction. Waveform C are the pulses provided at the output 183, designating the occurrence 194 of the right ventricular contraction. Waveform D are the pulses provided at the output 184, designating the occurrence 195 of the left ventricular contraction at the site of patch implantation. Pulse 193 occurs after certain delay succeeding the P-wave 190 which is a normal delay of the cardiac muscle contraction after the cardiac muscle depolarization. Because of the same reason, pulses 194 and 195 occur after certain delay succeeding the QRS complex 191. There is a slight delay interval 196 of pulse 195 after the pulse 194 which is the delay of left ventricular patch tension after the ventricular lead tension. Delay interval 196 usually increases if ventricular tachycardia occurs, but may be also vice versa. Different delay interval durations distinguish different ventricular tachycardias. In certain ventricular tachycardias pulse 195 may occur before the pulse 194. There are two tensiometric atrio-ventricular intervals 197 and 198. In the case of supraventricular tachycardia, these atrio-ventricular intervals change, a specific tachycardia having characteristic ration of these two atrio-ventricular intervals duration. Therefore every cardiac rhythm, either natural of pathologic may be defined by means of three tensiometric intervals 196, 197 and 198. This means that every cardiac rhythm has a distinctive sequence of pulses 193, 194 and 195. Measurement of this sequence is used for tachycardia detection and differentiation between various types of tachycardias.

It is understood that the outputs 182, 183 and 184 are connected to the microprocessor of an electrotherapy device. Specific pulses sequence for specific tachycardia is memorized within the microprocessor memory during intentionally provoked episode of tachycardia in electrophysiologic study session. Detection of the specific pulses sequence, within the

certain allowed margins of timing accuracy, may initiate a certain antiarrhythmic mode of electrotherapy.

Fig. 2 can also illustrate completely another possible embodiment of the present invention.

- 5 As it is known in the art, the outputs of amplifiers 173, 174, and 175 could be also connected to sample-and-hold circuits 176, 177 and 178, as well as to the analog to digital convertors 179, 180 and 181. In that kind of embodiment, the outputs 182, 183 and 184 would be connected to the digital input ports (not disclosed) in order to supply a microprocessor circuit (not disclosed) with digital form of tensiometric transducers' signals. In
- 10 such kind of device, the voltages produced by transducers 170, 171 and 172 could be measured and compared by means of the appropriate software. Some tachycardias decrease the magnitude of the contraction at the certain region of the cardiac muscle. Some tachycardias change the ratio of magnitudes of contractions of the two different regions. The output voltage amplitude of the piezoelectric transducer is proportional to the
- 15 magnitude of the cardiac contraction being measured by the transducer. Accordingly, mutual ratios of voltage amplitudes generated by the transducers 170, 171 and 172 represent the mutual ratios of magnitudes of the tensions of leads 150 and 151 as well as of patch 157. For instance, the ration of voltages generated by the transducers 171 and 172 represents the certain ventricular rhythm. It will be significantly different in ventricu-
- 20 lar tachycardia, compared with the sinus rhythm. Moreover, it will be different in two ventricular tachycardias having different electrophysiologic origin. Furthermore, the ration of voltages generated by transducers 170 and 171 will be significantly different in supra-ventricular tachycardia compared to the sinus rhythm.
- 25 The electrotherapy device having both disclosed measurement systems i.e. contraction sequence and regional contraction magnitude ratio variation would have a powerful means for cardiac arrhythmias recognition and classification.

Although I have described my invention in detail with reference to the accompanying
30 drawing illustrating preferred embodiments of my invention, it is understood that numerous

changes in the details of construction and arrangements of parts may be made without departing from the spirit and scope of the invention as hereinafter claimed.

Claims

1. A cardiac electrotherapy device comprising:
5 at least two cardiac electrotherapy leads (151, 157),
said leads comprising sensor portions (160, 157) adapted to detect cardiac contractions in two different regions (156, 158) of the heart through a deflection of said leads (151, 157),
electronic circuitry (173-181, 185) connected to or connectable to said leads
10 and adapted to generate cardiac contraction data signals (B, C, D) corresponding to a detection by said sensor portions, and
cardiac arrhythmia detection means operating in response to said cardiac contraction data signals and capable of detecting cardiac arrhythmia therefrom.
- 15 2. Device according to claim 1, comprising means for terminating cardiac arrhythmia, and electronic circuitry for cardiac electrotherapy.
3. Device according to claim 1 or 2, wherein each of said leads (151, 157) comprises a transducer (171, 172) generating a signal having an amplitude proportional to
20 the magnitude of cardiac contraction at the cardiac region wherein said lead is implanted (156) or whereon said lead is attached (158),
said signal occurring at the onset (194, 195) of cardiac contraction of the cardiac region wherein said lead is implanted (156) or whereon said lead is attached (157).
- 25 4. Device according to any of claims 1 to 3, wherein said electronic circuitry for generating cardiac contraction data signals comprises means for calculation of a time interval (196) representing the contraction timing between said two regions of the heart (156, 158),
means for beat to beat comparison of said time interval, and
30 means for detection of sudden change of duration of said time interval in a

single beat, said sudden change indicating that said single heart beat is a ventricular premature contraction.

5 5. Device according to claim 4, wherein said electronic circuitry for generating cardiac contraction data signals comprises means for detection of sudden change of duration of said time interval in a series of heart beats,

 said sudden change indicating the initiation of cardiac arrhythmia and activating said means for terminating cardiac arrhythmia.

10 6. Device according to claim 3, wherein said electronic circuitry for generating cardiac contraction data signals comprises

 means for amplitude measurement of the two signals of said transducers,

 means for beat to beat comparison of said amplitudes

 and means for detection of sudden change of ratio of said amplitudes in a single
15 beat, said sudden change indicating that said single heart beat is a ventricular premature contraction.

 7. Device according to claims 6, wherein said electronic circuitry for generating cardiac contraction data signals comprises means for detection of sudden change of
20 ration of said amplitudes in a series of beats,

 said sudden change indicating the initiation of cardiac arrhythmia and activating said means for terminating cardiac arrhythmia.

 8. A cardiac electrotherapy device comprising
25 at least two cardiac electrotherapy leads (151, 157) capable to measure cardiac contractions,

 electronic circuitry for cardiac electrotherapy and electronic circuitry for cardiac contractions measurement, timing and processing of the cardiac contractions data of the two different regions of the heart (156, 158),

30 said device comprising means for cardiac arrhythmia detection and means for

terminating cardiac arrhythmia,

wherein said means are controlled by means of processing of the signals generated within said leads (151, 157) by cardiac contractions at the two different regions of the heart (156, 158).

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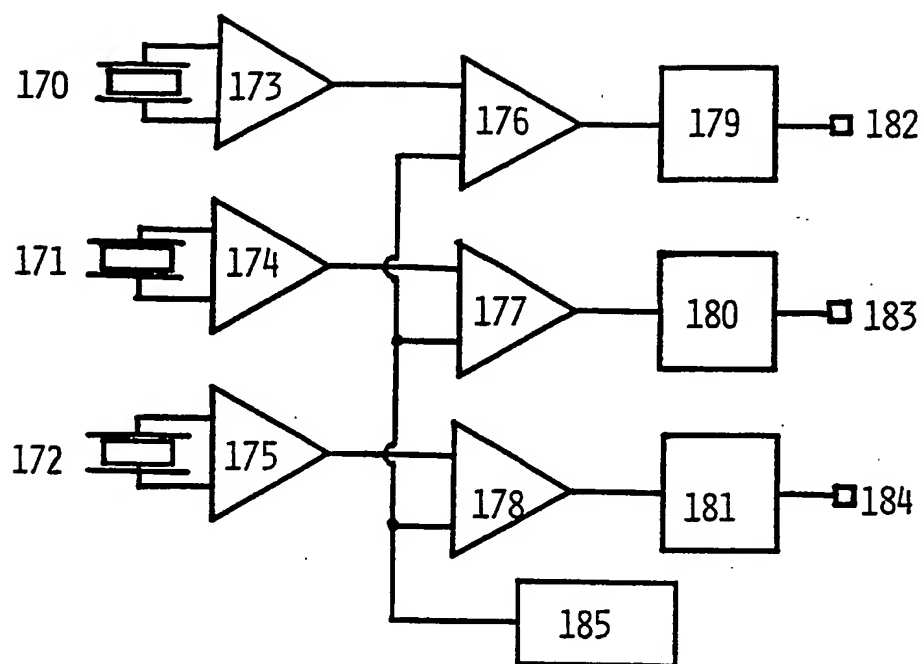


FIGURE 2

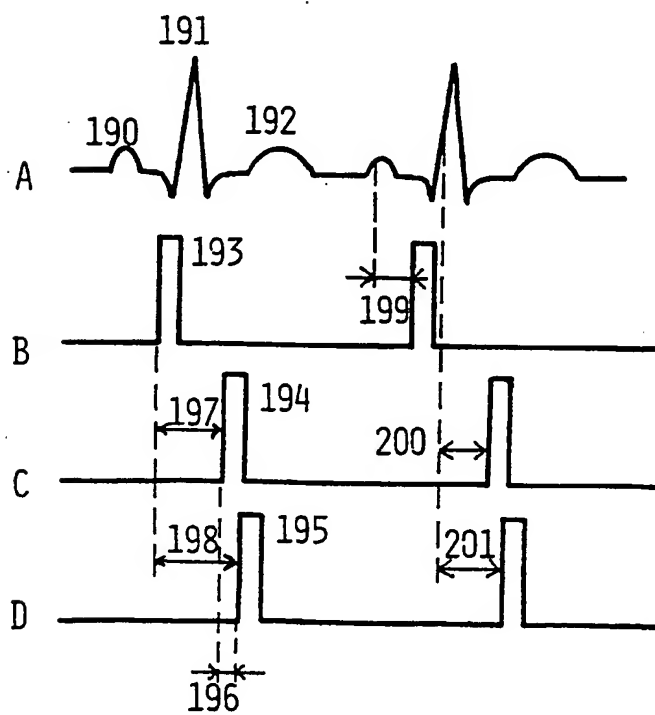


FIGURE 3

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 95/00113

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61N1/365

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR,A,2 166 812 (MEDTRONIC) 17 August 1973 see abstract; claims 1,7,13 see page 3, line 27 - page 4, line 12 see page 5, line 26 - line 28 ---	1,2,8
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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Inter. nal Application No

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